CORROSION AND CORROSION PROTECTION

TYPES OF CORROSION

- SURFACE RUSTING
- PITTING CORROSION
- STRESS CORROSION
- HYDROGEN EMBRITTLEMENT

ANODIC CORROSION

- NEEDS:

- A DIFFERENCE IN ELECTRIC POTENTIAL
- THE PRESENCE OF AN ELECTROLYTE
- OXYGEN

FORMATION OF CORROSION ELEMENTS

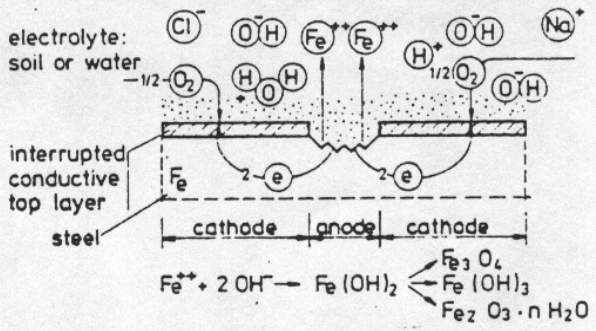
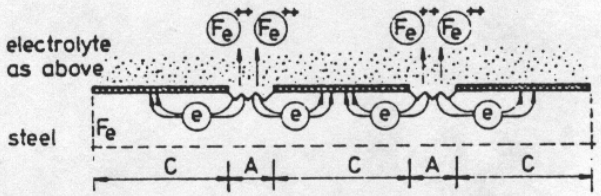
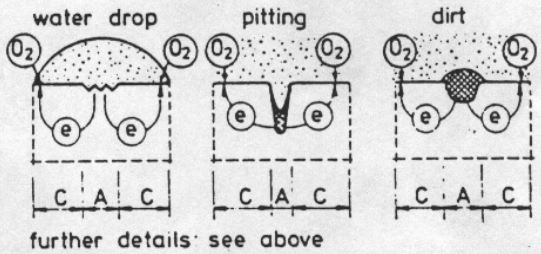
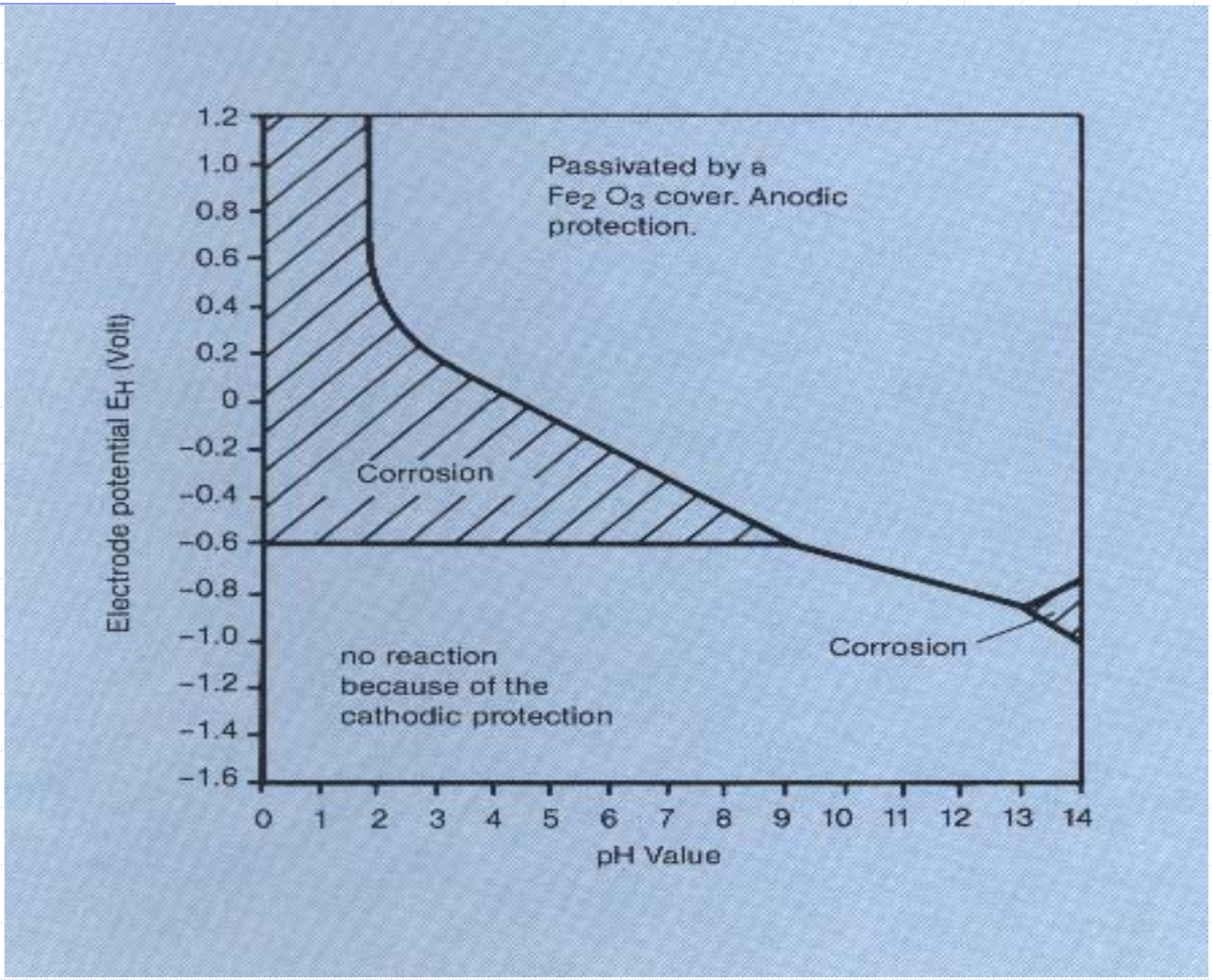
cause for formation of corrosion cells	examples of corrosion cells
conductive layers e.g. rolling scale	
heterogeneous surface e.g. localized oxide film	
differential aeration of steel surface	

DIAGRAM OF POURBAIX



HYDROGEN EMBRITTLEMENT

- FAVORED BY:

- HIGH STRESS
- PRESENCE OF WATER
- DEFFICIENCY OF OXYGEN
- LOCALLY LOWER PH-VALUE
- PRESENCE OF SULFIDES
- HIGH STRENGTH STEEL

RATE OF CORROSION

- DEPENDS ON:

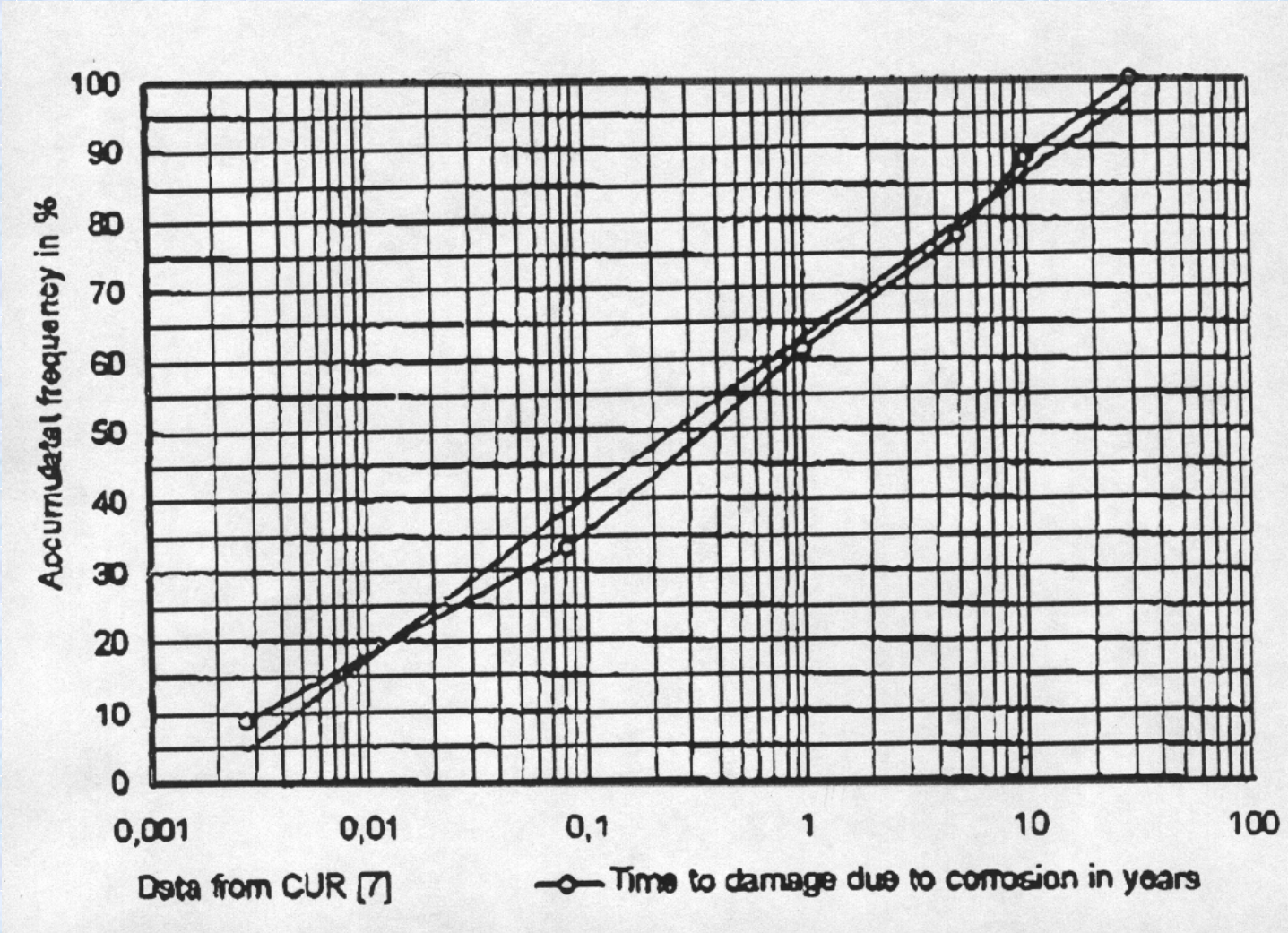
- RESISTANCE OF THE ELECTROLYTE
- DIFFERENCE IN ELECTRIC POTENTIAL
- PRESENCE OF AERATED ELEMENTS
- TEMPERATURE
- TYPE OF STEEL

FIP ACCELERATED CORROSION TESTS

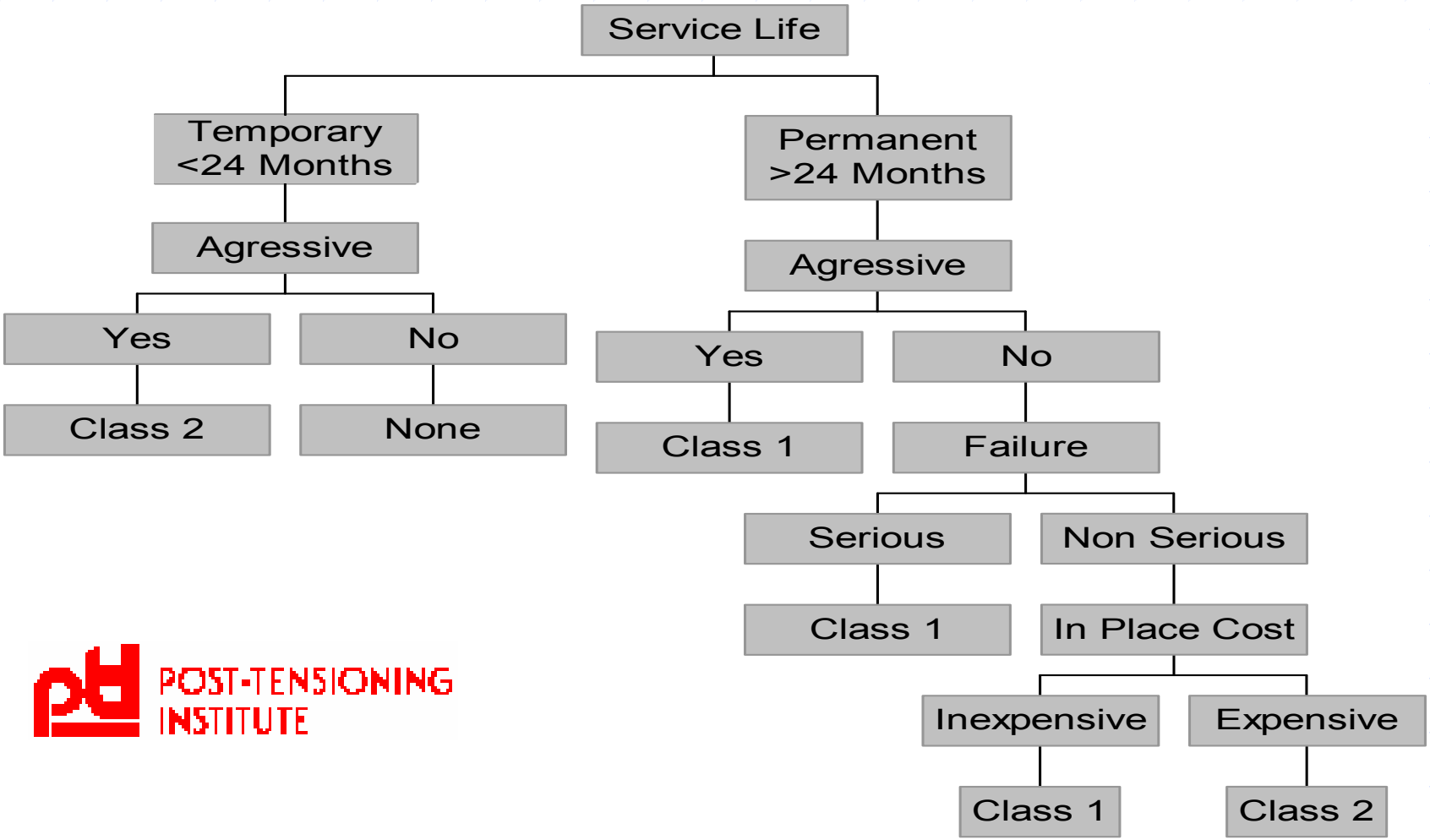
BY LUCIUS PITKINS IN A 20% AMMONIUM THIOCYANIDE @ 50 C STRESSED TO 0.8 Fu

Number	Specimen	Diam	Cross-sectional area	Mechanical properties		Time to failure — t (hr), (f) = percentile in a gaussologarithmic plot					Remarks
				Tensile strength	Yield strength						
	Material	mm	mm²	N/mm²	N/mm²	min	max	$t(f) = 10$	$t(f) = 50$	$t(f) = 90$	
2	130/145 SiCr HT bar	9.08	64.8	1481	1383	198.35, 211.20 (a), 211.30					(a) Specimen did not fail (3 specimens tested)
3	130/145 SiCr HT bar (D)	9.15	64	1462	1374	5.25	> 200	3.2	29	> 200	(9 specimens tested)
4*	110/125 SiCr HT bar	31.47	777.8	1268	1120	213.7, 263.3, 210.9					Specimens did not fail (3 specimens tested)
6	ASTM A 722 Bar (D)	32.2	814.3	1156	1038	214, 213.2					Specimens did not fail (2 specimens tested)
13	Center wire of 7 wire strand (U.S.)	5.24	21.57	1914	1737	7.1, 2.7					(2 specimens tested)
14	ASTM A 416 7 wire strand (U.S.)	9.52	51.77	2000		4.8, 6.2					(2 specimens tested)

ACCUMULATED FREQUENCY OF CORROSION DAMAGES



CORROSION PROTECTION DECISION TREE



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DEFINITION OF AGGRESSIVE GROUND

Ground is aggressive when:

- pH less than 4.5
- Resistivity less than 2,000 ohm-cm
- Chemical composition (sulfites)
- Ground water

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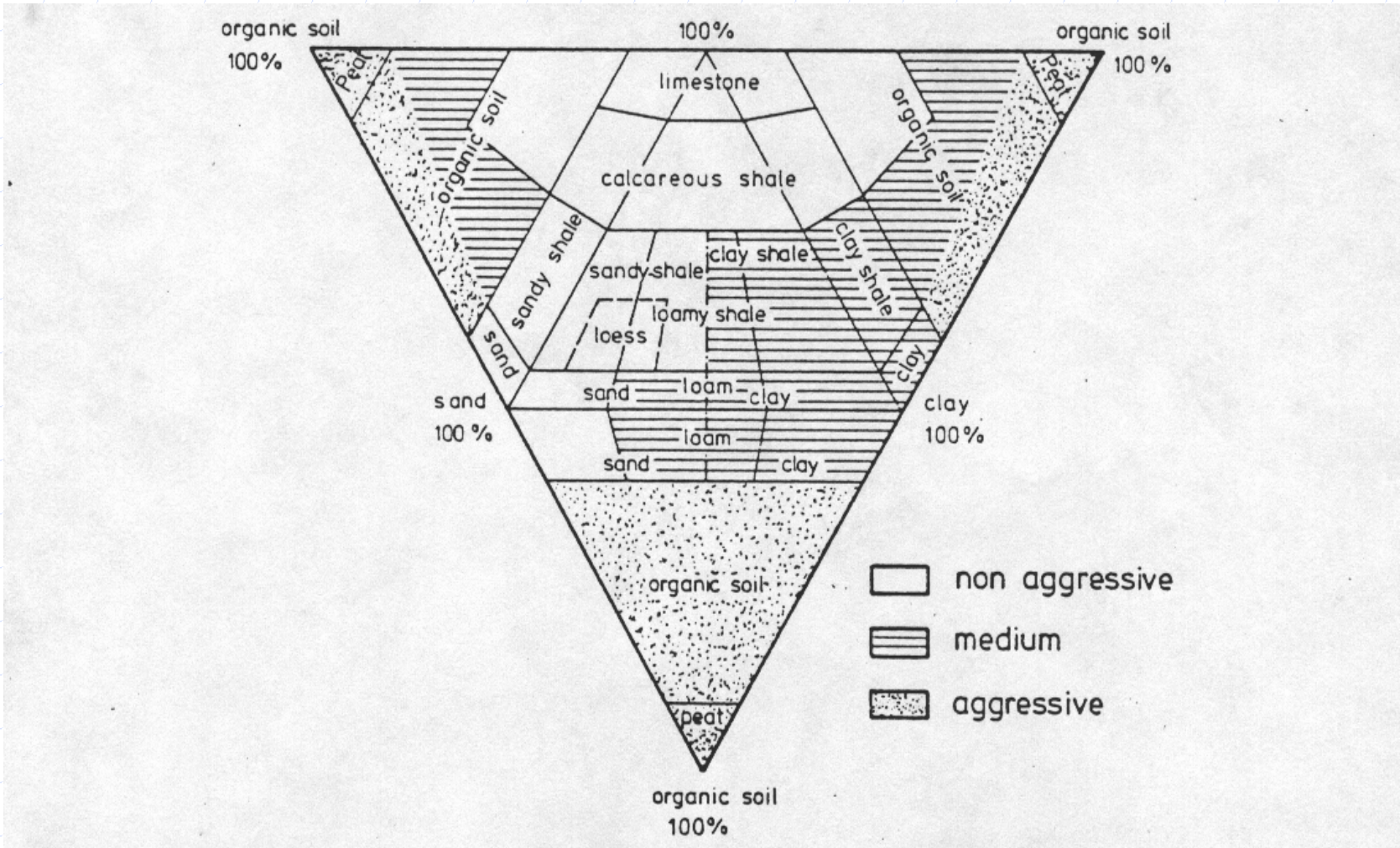
AGGRESSIVITY OF SOILS



CORROSION PROTECTION REQUIREMENTS

CLASS	PROTECTION REQUIREMENTS		
	ANCHORAGE	UNBONDED LENGTH	TENDON BOND LENGTH
I ENCAPSULATED TENDON	1. TRUMPET 2. COVER IF EXPOSED	1. GREASE-FILLED SHEATH, OR 2. GROUT-FILLED SHEATH, OR 3. EPOXY FOR FULLY BONDED ANCHORS	1. GROUT-FILLED ENCAPSULATION, OR 2. EPOXY
II GROUT PROTECTED TENDON	1. TRUMPET 2. COVER IF EXPOSED	1. GREASE-FILLED SHEATH, OR 2. HEAT SHRINK SLEEVE	GROUT

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CLASS I & CLASS II PROTECTION

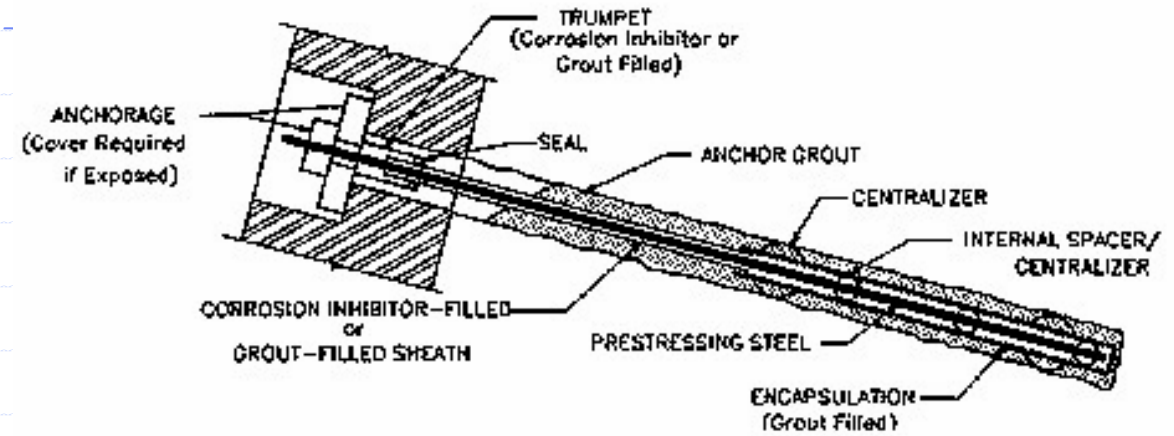

Figure 5.1 Class I Protection – Encapsulated Anchor

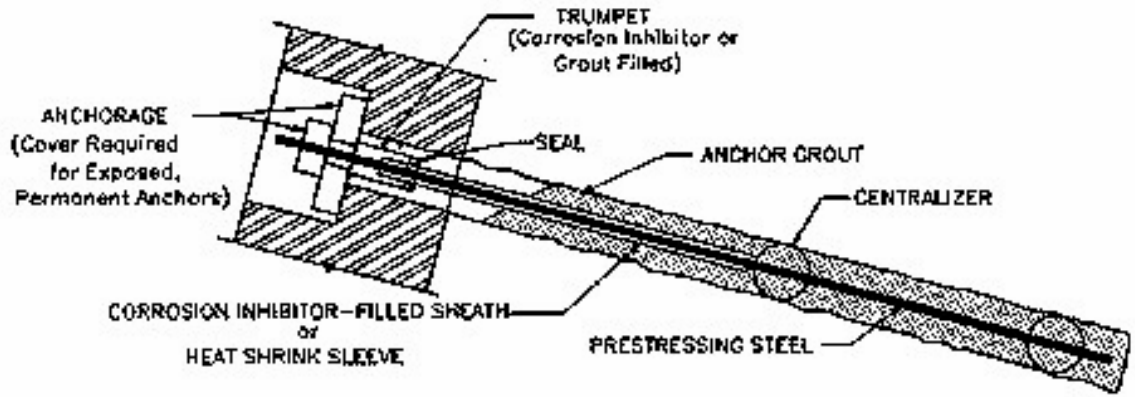

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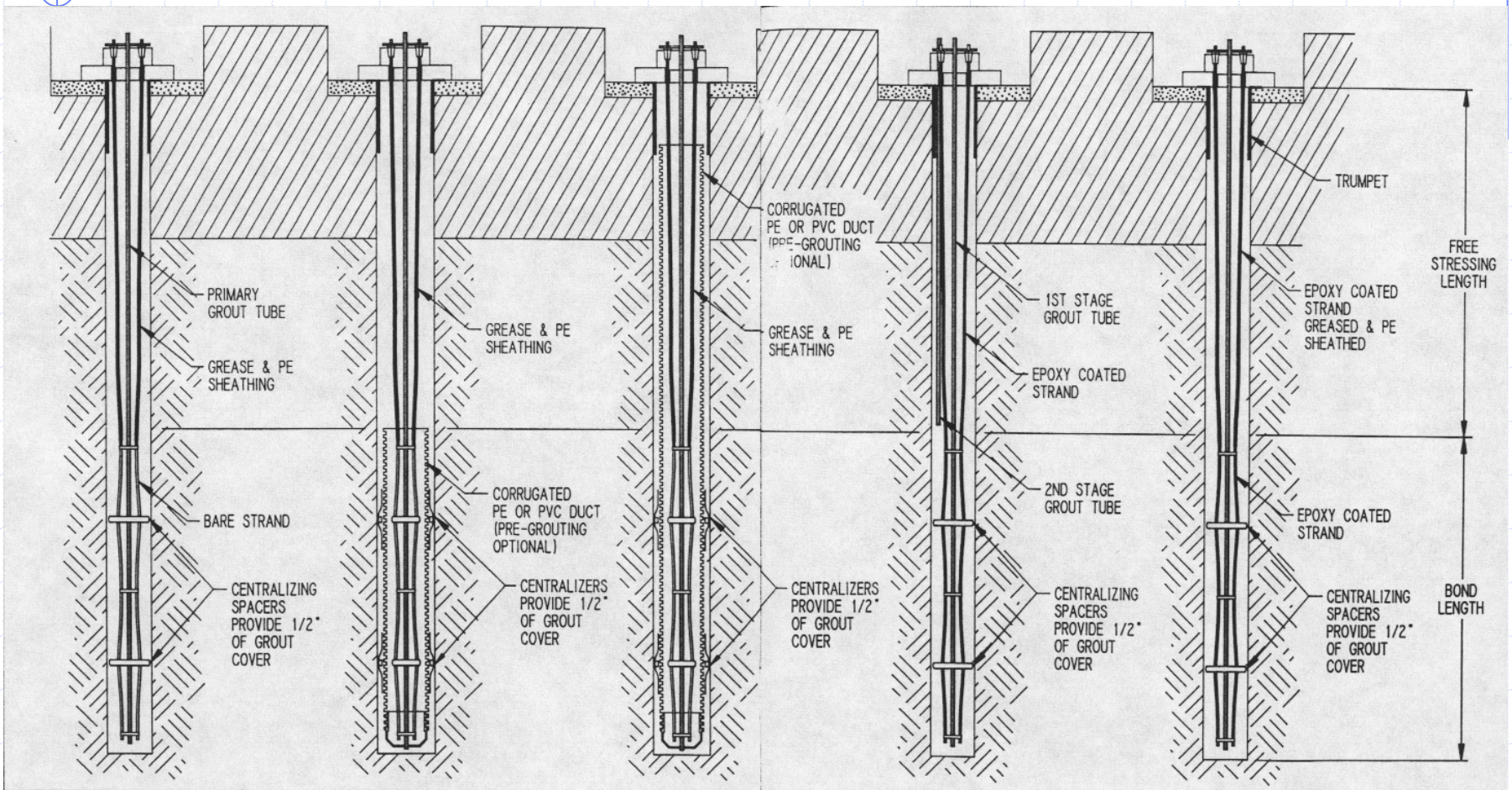
Figure 5.2 Class II Protection - Grout Protected Anchor

MULTI-STRAND ANCHORS



A	B	C	D	E	ANCHOR TYPE
SCP	DCP	DCP	DCP	DCP	CORROSION PROTECTION
SINGLE STAGE	SINGLE STAGE	SINGLE STAGE	TWO STAGE	SINGLE STAGE	GROUTING

PROPERTIES FOR PLASTIC SHEATHING

Properties	Unit	high density PVC		PPH		high density PE	
		value	test method according DIN	value	test method according DIN	value	test method according DIN
yield stress (tensile strength)	N/mm^2	50	53455	33	53455	21-28	53455
strain at yield stress	%	12	53455	20	ISO/R 527	16	ISO/R 527
ultimate strength	N/mm^2	>45 e.g.53	53455	41	speed = 125 mm/min	32-40	method E
strain at ultimate strength	%	100	53455	800		800	53455
bending creep modulus (1 min)	N/mm^2	2950	53457	1200	53457	1500	53457
Shore hardness		D 83	53505	D 62	53505	D 60	53505

PROPERTIES OF CORROSION PROOF COMPOUNDS

Property	Units	Test method	Proposed acceptence values
content of free sulphur and sulphides	ppm	DIN 51759 ASTM D-130-75	≤ 10
content of ionic chlorides nitrates rhodanides	ppm " "	ASTM D512 } DIN 51576 ASTM D992 } DIN 51576	≤ 10 ≤ 10 ≤ 10
spec. resistivity	Ω.cm	DIN 53482	> 10
water absorption 0.1 N KOH, after 30 days	%	DIN 53495	≤ 2
saponification (acidity)	mg KOH/g	DIN 53401 ASTM D 94-91	≤ 10
deoiling on filter paper at 50° C ,after 7 days	dia mm	no standard specimen dia 20 mm	≤ 100
penetration depth at deoiling test on hardened cement grout at 50° C after 7 days	dia mm	no standard	≤ 2
thermal stability, 24h	°C	10% inclined channel 26x18 mm with sieve at lower end, mesh width 0,5 mm	≥ 40
drop point	°C	DIN 51801	≥ 60

GREASE

- CONSISTS OF:
  PETROLEUM OIL
  CORROSION PREVENTIVE ADDITIVES
  ORGANIC SOAP

RESISTANT TO BUT NOT INSOLUBLE IN WATER

WAX

- CONSISTS OF:
  MICROCRYSTALLINE WAX (HYDROCARBONS)
  PETROLATUMS (OILS AS A SOFTENER)

HIGH MELT POINT
INERT IN CONTACT WITH WATER

WAX VERSUS GREASE

- WAX DOES NOT DEOIL IN HOT TEMPERATURES
- WAX DOES NOT LOOSE OIL WHEN IN CONTACT WITH GROUT
- WAX DOES NOT DECOMPOSE IN WATER
- WAX MORE RESISTANT TO HYDROSTATIC PRESSURE

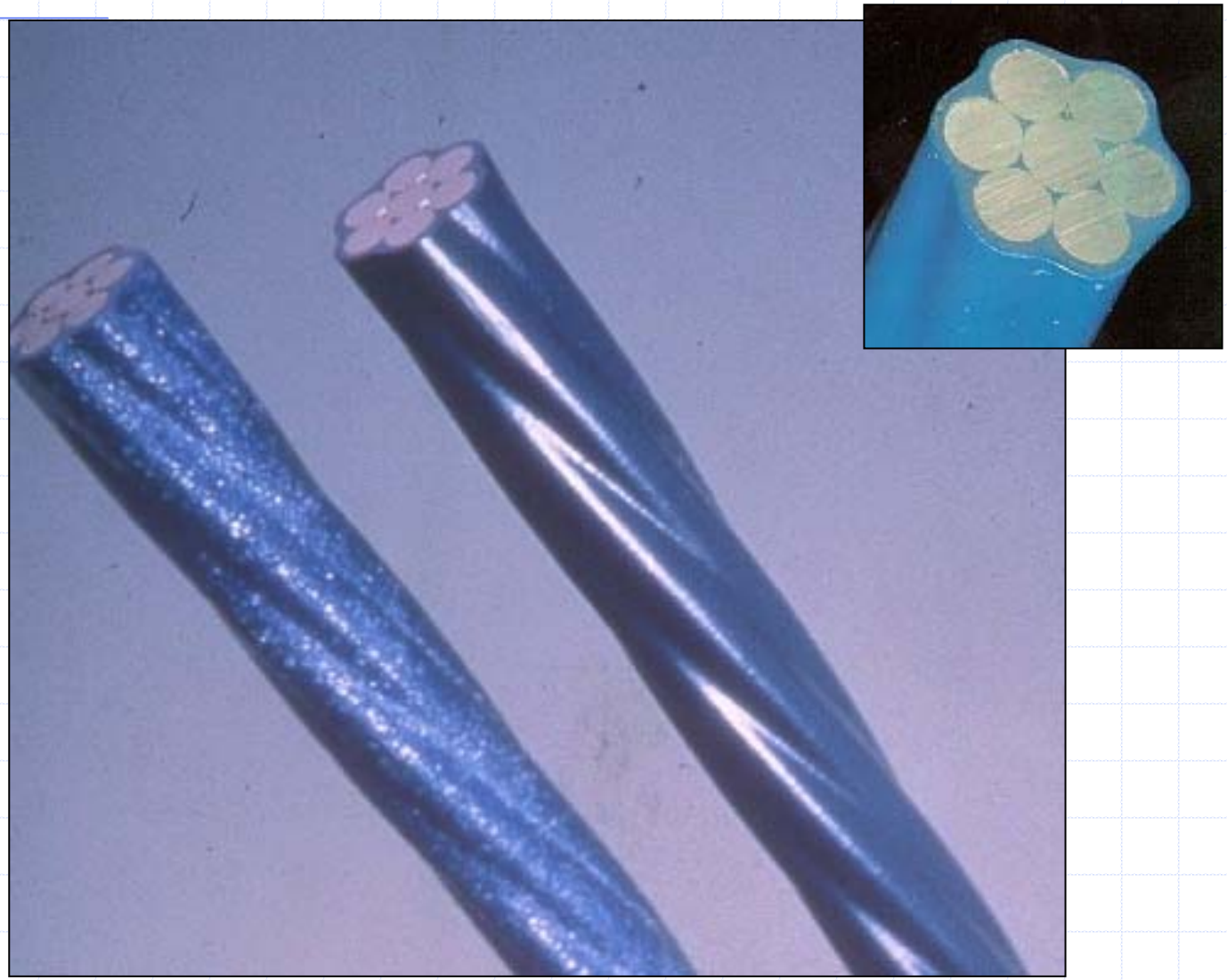
5 SAMPLES, October 2000

5 SAMPLES, October 2000

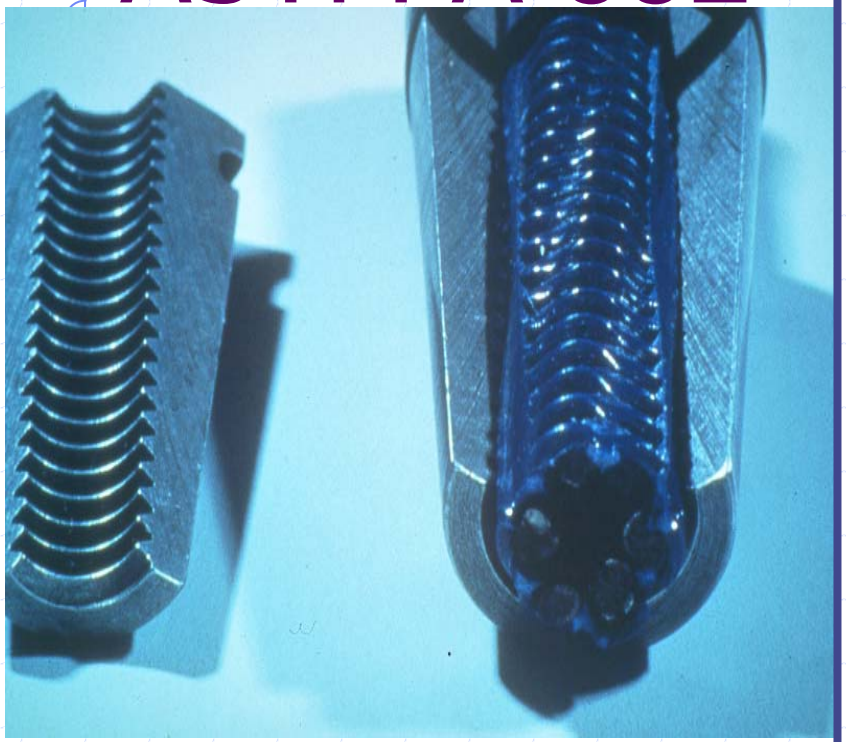
5 SAMPLES, October 2000

WATER IMMERSION TEST

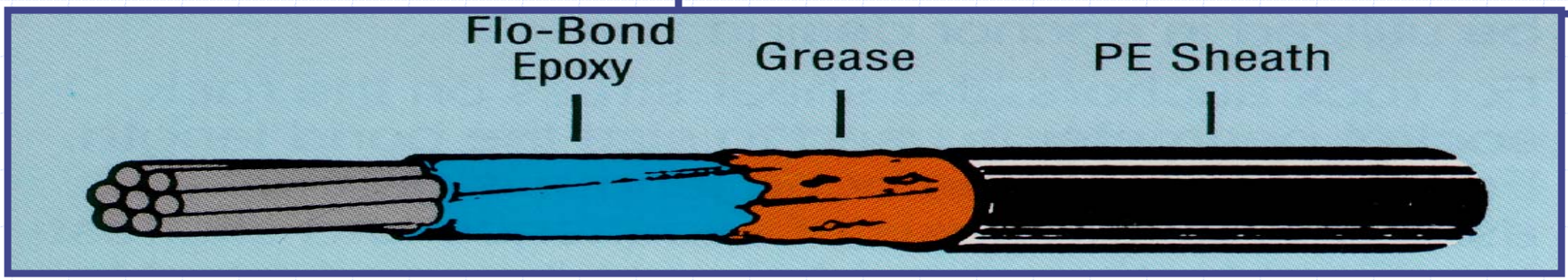
EPOXY COATED STRAND



EPOXY-COATED STRAND, ASTM A 882



- Individual wires are coated(15-40mil thickness)
- Special design wedge
- Grid to enhance bond to grout
- Good corrosion protection(no need for corrugated sheathing)
- Smaller drilled hole diameter
- Prefabricated, ready for installation
- Special un-coiler and stressing equipment
- Large capacity ground anchors (Retrofit/New)
- Post Tensioning(Cable Stay bridges)



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